1 Introduction

1.1 Preface

1.1.1 Background

Many users of geospatial data within both the transportation and GIS communities have questions about the relationships among transportation features such as roads, their representation as geo-spatial objects in geographic information systems (GIS), and their representation in analytical networks. Much of this confusion results from the inconsistent use of terminology to describe transportation features and their representations. It is also perpetuated by current versions of GIS software, which fail to adequately address the differences between lines used for cartographic displays and those used for network analysis.

1.1.2 Need for Standards

One consequence of this confusion has been an inability to promulgate national standards for transportation spatial features to facilitate data sharing under the **National Spatial Data Infrastructure (NSDI)** initiative. A fundamental requirement of spatial data sharing is that both the supplier and the recipient of the data understand what the data represents in terms of real-world features. This is relatively straightforward for features having well defined boundaries such a building or airport. However, many transportation features are characterized by extensive linear networks, with no universally agreed upon standard for partitioning these networks into unique "segments." Each developer of a transportation network spatial database partitions the network to meet his or her specific application needs.

1.1.3 FGDC Action

The **Federal Geographic Data Committee (FGDC)** was established by the Office of Management and Budget (OMB) under Circular A-16 to promote the coordinated development, use, sharing, and dissemination of geographic data. The committee, which is composed of representatives from 17 departments and independent agencies, oversees and provides policy guidance for agency efforts to coordinate geographic data activities. The FGDC created the **Ground Transportation Subcommittee** in January 1992 to address data issues involving transportation features and networks. The objectives of the Subcommittee are to:

-- promote standards of accuracy and currency in ground transportation data which is financed in whole or in part by Federal funds;

-- exchange information on technological improvements for collecting ground transportation data;

-- encourage the Federal and non-Federal community to identify and adopt standards and specifications for ground transportation data; and

-- promote the sharing of ground transportation data among Federal and non-Federal organizations.

1.1.4 NSDI Framework Data

Transportation is one of the seven Framework layers identified in the National Spatial Data Infrastructure. NSDI framework data represents the "best" available geo-spatial data for an area. The data is collected or compiled to a known level of spatial accuracy and currency, documented in accordance with established metadata standards, and made available for dissemination at little or no cost and free of restrictions on use. Framework data is not necessarily uniform from one area to another; the quality of the data for a given area depends on the requirements of the participating data developers. The NSDI does not specify threshold standards for spatial accuracy, attribution, completeness of coverage, or currency for any of its framework themes. The resulting framework will be a "patchwork quilt" consisting of high quality geo-spatial data for some geographic areas, with lower quality or even missing data for other areas. As more data developers upgrade their geo-spatial data and participate in the NSDI, the overall quality of the data comprising the NSDI Framework and the completeness of nationwide coverage will improve. For further information see the FGDC publication “NSDI Framework Introduction and Guide,” http://www.fgdc.gov/framework/frameworkintroguide/ .

1.1.5 The Transportation Framework Data Layer

The importance of geo-spatial data depicting transportation features – especially road networks – extends well beyond their cartographic value. Road networks provide the basis for several indirect location referencing systems, including street addresses and various linear referencing methods commonly used to locate features like bridges, signs, pavement conditions, and traffic incidents. Geo-spatial transportation segments can be connected to form topological networks, which can be used to more accurately measure over-the-road travel distances between geographic locations. Furthermore, when combined with the variety of network analysis tools that are available, topological networks can be used to find the shortest paths between two or more locations, to determine the most efficient route to cover all transportation segments (e.g., for planning of snow removal), or to estimate traffic volumes by assigning origin-to-destination flows to network segments.

Integration of the “best available” transportation databases into a national framework layer must provide for nationwide connectivity in order to support the network applications described above. This means that there can be no “gaps” (geographic areas where transportation data is totally absent). Further, the transportation data for each particular geographic area must be produced so that it can be connected topologically to transportation data for adjacent areas.

1.1.6 Federal, State and Local Transportation Data Resources

A nationwide NSDI framework road layer *could* be constructed from the national level databases developed by federal agencies: **Bureau of the Census** TIGER/Line files, **U.S. Geological Survey** Digital Line Graph (USGS/DLG) files, and the National Highway Planning Network (NHPN) developed by the **Federal Highway Administration** (FHWA). These databases serve most federal needs and many general public requirements for national level road data at the 1:100,000 scale, and provide network connectivity in those areas where more accurate transportation data does not exist. However, such a database would not offer the currency, completeness, and accuracy required by many other users.

Over half of the state Departments of Transportation (DOTs) have developed road databases at a scale of 1:24,000 or better. These databases are almost certainly of superior accuracy, completeness and currency than the national databases, and *could* take the place of federal road data as the framework database for their respective areas, providing they meet other NSDI framework requirements (e.g., metadata documentation, no restrictions on use). Road data which is even more accurate and current exists for many smaller geographic units; e.g. counties or metropolitan areas. These databases *could* be utilized instead of either the federal or state transportation data as the framework database for their specific areas.

1.1.7 The Challenge

Creation of the NSDI framework transportation layer will require the participation of a large number of federal, state, and local transportation agencies, and their contribution of transportation databases developed for specific geographic areas and applications. The databases will be – or have been – developed at different scales, with different levels of positional accuracy, detail and completeness of coverage, and currency. These databases will have to be "stitched together" in order to provide the network connectivity required for many transportation applications. When new databases are added to the framework, or when specific attributes are updated or enhanced, users of framework data will need to be able to incorporate this new information into their applications in ways that are cost-effective.

The process of transferring information (including more accurate coordinates) from one geo-spatial database to another is known as "conflation." Successful conflation requires that the features in one geo-spatial database be matched to their counterparts in the other database. Once this match is achieved, geometric and/or attribute data can be exchanged from either of the two databases to the other. For example, coordinate data depicting the alignment of a transportation segment can be transferred from a transportation database digitized from 1:12,000 scale digital orthophotoquads (DOQs) to a database that had originally been digitized from 1:24,000 scale USGS topographic maps.

Typically the process of conflation uses a combination of coordinate matching and name matching. Depending on the similarity of the two databases, the percentage of successfully matched features can vary from over 90 percent to well under 50 percent. This range of variability is unacceptable for successful implementation of the NSDI framework, which will require ongoing additions of new framework databases and transactional updates to attributes in existing framework databases.

A more promising conflation method starts with the assignment of a stable and unique identifier to each geo-spatial feature. This identifier can then be used to match features across databases without having to rely on coordinate accuracy or the use of standard names. Unique feature identifiers work best when instances of features are well defined and spatially distinct.

The identification of a discreet feature instance is not always obvious for linear features such as roads and surface waters. Roads are segmented in an almost infinite number of ways, depending on the application needs of the database developer. Roads may be segmented at intersections for path building, or at changes in one or more attributes for use in facility management. Also, a transportation segment may terminate at a state, county, or municipal border, or other jurisdictional boundary.

Within the same geographical area multiple entities may create, update, and/or use different transportation databases. For example, a state DOT may create a transportation database that includes only state highways, and may segment its roads wherever one highway intersects another. A local transportation planning agency might create a database for the same area that includes all local roads; this agency could segment the state highways wherever they intersect any road. Finally, an E-911 agency could create yet a third transportation database for the area, segmenting all roads at each private driveway.

Most geographic information system (GIS) software packages currently do not enable the user to distinguish between an instance of a linear geo-spatial feature and how that feature is represented in a topological network. Each of the transportation databases mentioned above represents the same physical transportation network but divides it into different – often overlapping – segments in order to establish topological connections needed for the respective applications. Each segment becomes a distinct record in the geo-spatial database unique to that application. Finding a set of common transportation segments that carry topology and are useful in all existing and potential applications is impossible in most geographic areas.

The concept of a permanent transportation segment identifier is attractive, but the need to add new transportation segments to accommodate other applications or to reflect changes in infrastructure can create problems. Consider the case of a road segment (`Segment_A`) with an assigned permanent identifier, as illustrated in Figure 1. A new road (`Segment_B`) is built which intersects the old road segment part way along its length. In order to maintain network topology, the old road segment must be split and a node established where the new road intersects. The identifier for the old road segment is no longer valid. It must be retired and three new identifiers created: one for the new intersecting road (`Segment_B`) and one for each new segment (`Segments_AA` and `AB`) of the (now split) old road segment. Recording, disseminating, and applying these transactions could become prohibitively complex or time-consuming, both for the database developer and for users trying to incorporate the updated information into their own application database.

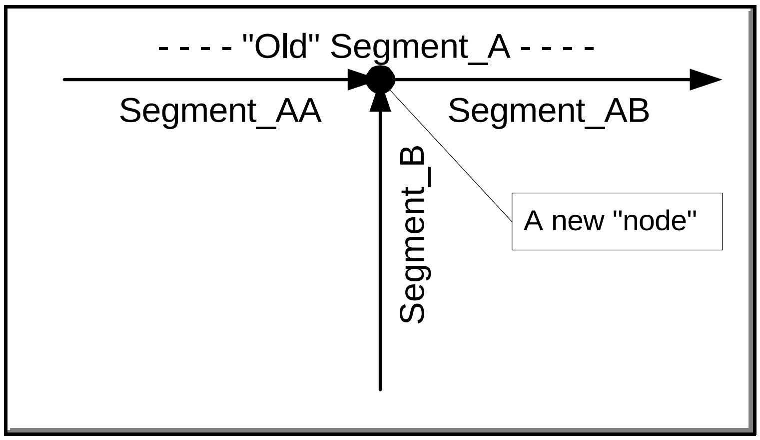

Figure 1 - Intersecting Road Segments

In summary, the growing needs of users make the argument for constructing an NSDI framework transportation data layer(s) a compelling one. Also, all users will benefit if the investments in high quality transportation information being made by many units of state and local government can be incorporated. The related technical requirements present a challenge in the development of standards, technology and procedures which will be needed in order to accomplish this task.

1.2 Conventions used in this Standard

The following conventions for forms of values for data elements are used in this Standard:

1.2.1 Calendar Dates

Values for day and month of year, and for years, shall follow the calendar date convention (general forms of YYYY for years; YYYYMM for month of a year (with month being expressed as an integer), and YYYYMMDD for a day of the year) specified in American National Standards Institute, 1986, Representation for calendar date and ordinal date for information interchange (ANSI X3.30-1985): New York, American National Standards Institute (adopted as Federal Information Processing Standard 4-1).

1.2.2 Latitude and Longitude

Values for latitude and longitude shall be expressed as decimal fractions of degrees. Whole degrees of latitude shall be represented by a two-digit decimal number ranging from 0 through 90. Positive numbers indicate North latitude; negative numbers indicate South latitude. Whole degrees of longitude shall be represented by a three-digit decimal number ranging from 0 through 180. Positive numbers indicate West longitude; negative numbers indicate East longitude. When a decimal fraction of a degree is specified, it shall be separated from the whole number of degrees by a decimal point. This form is specified in American National Standards Institute, 1986, Representations of Geographic Point Locations for Information Interchange (ANSI X3.61-1986): New York, American National Standards Institute.

1.2.3 Numeric Values

Values for distance and other measures are specified as a specific number of characters; this specification includes characters for plus (+) and minus (-) signs and decimal points (.) whenever appropriate. Many users will operate applications which store, compute, or analyze these attributes in a variety of "numeric" field formats, but they should be able to import and export these standardized data in the character field formats specified.

1.3 Justification

1.3.1 Objective

The objective of this content standard is to specify methods for identifying linear geo-spatial features that can be implemented within existing data structures without some of the topological problems cited above. Furthermore, the proposed standard should allow users to create customized topological networks from the reference segments without modifying the properties of the reference segments themselves. Successful achievement of this objective will facilitate transactional updates to framework transportation databases by allowing new transportation features to be added without changing existing transportation segments. The standard should define a transportation segment in such a way that it is independent of cartographic representation – irrespective of scale, attributes which can change over time, and network topology. Each defined transportation segment can then be assigned a unique identifier that does not need to be modified for different applications or for additions of new transportation features.

Establishment of stable transportation segment identifiers will facilitate the exchange of information between databases; e.g., improved geo-spatial coordinates, feature attributes like road names, or controls to various linear referencing methods like beginning and ending mile points, or low and high address values.

The **NSDI Framework Transportation Identification Standard** defines the collection of objects which serve as the basis for transferring information among different networks, higher level linear referencing systems, and cartographic representations of roads. The standard relates multiple cartographic and topological network data base representations to uniquely identified transportation segments in the real world, and provides the domain for transferring application attributes across linear referencing and cartographic systems.

The model consists of a set of one-dimensional **Framework Transportation Segments (FTSeg)** that have zero-dimensional **Framework Transportation Reference Points (FTRP)** at their termini. FTRP and FTSeg are highly stable, unambiguously identified, and recoverable in the field.

The standard is not intended to be a geodetic or linear datum. It contains no specification for either coordinate or linear measurement accuracy. However, the standard does provide a structure for accommodating a linear datum by including coordinates and length measures as attributes, and by requiring accuracy statements whenever such measures are specified. This enables users to assess the suitability of the geometry or attributes from one or more transportation databases for their particular application(s).

1.3.2 Scope

The NSDI Framework Transportation Identification Standard is being proposed as an "FGDC data content standard." It includes both standards for assigning and reporting identification codes as well as guidelines for data capture under the classification of a process standard.

Part II of this document provides a standard for identifying physical transportation segments that are temporally stable and independent of any cartographic representation, scale, level of detail, or network application. Any transportation databases considered to be compatible with the NSDI transportation framework layer must conform to this standard.

The data content standard includes a mandatory set of attributes for each Framework Transportation Segment (FTSeg), and a format for a unique identification code to be assigned to each identified segment. Each FTSeg begins and ends at a Framework Transportation Reference Point (FTRP); mandatory attributes and an identification code for each FTRP are also specified. Part II also specifies a process for assigning, modifying and recording FTRP and FTSeg identification codes, and proposes a national registry for their identification.

The standard articulated here can be extended in the future to cover other transportation features that could be represented as networks including railroads, commercial waterways, pipelines, and public transit guide ways. Other network layers will require different process standards for assigning and recording identification codes. These additional process standards are not included as part of this document.

Part III of this document is made up of technical appendices, including references, a glossary of relevant terms, examples, and further information. It includes guidelines for selecting and locating the reference points of appropriate transportation segments, as well as other implementation procedures. The user of this document need not follow the guidelines to be in conformance with the standard.

1.3.3 Applicability

This proposed standard will have widespread applicability for public-sector and commercial database developers and data users, because there are no national standards for identifying, segmenting, or representing transportation segments in digital geo-spatial databases. Each database developer segments transportation networks to satisfy his/her specific application needs; however, the segmentation may not be appropriate for other applications. Furthermore, there is no standard approach for documenting the relationship between a digitized transportation segment and the physical transportation feature that it represents. Consequently, the exchange of attribute information between two different transportation databases representing the same geographic area is difficult, time consuming and error prone.

The proposed national standard for identifying and documenting transportation segments will facilitate data exchange among different users by providing well defined, common reference segments that are tied to the physical transportation feature, rather than to any cartographic or network abstraction of that feature. It will allow users to create customized topological networks from the reference segments without modifying the properties of the reference segments themselves, and to make transactional updates to framework transportation databases.

1.3.4 Consistency with Other Relevant Standards & Policies

1.3.4.1 FGDC Standards

1.3.4.1.1 Spatial Data Transfer Standard (SDTS)

The purpose of the SDTS is to promote and facilitate the transfer of digital spatial data between dissimilar GIS software packages, while preserving information meaning and minimizing the need for information external to the transfer. Implementation of SDTS is of significant interest to users and producers of digital spatial data because of the potential for increased access to and sharing of spatial data, the reduction of information loss in data exchange, the elimination of the duplication of data acquisition, and the increase in the quality and integrity of spatial data. SDTS is neutral, modular, growth-oriented, extensible, and flexible -- all characteristics of an "open systems" standard.

The SDTS includes conceptual models and definitions for spatial objects; a partial glossary of geo-spatial features; and standardized files structures and encoding specifications. The SDTS accommodates all forms of spatial data representation including raster, vector and graphical objects. In its general form, it is too complex to be implemented within a single translation software program. Instead, more restrictive SDTS profiles are being developed to transfer a specific type of spatial data. To date, profiles have been developed for planar topological vector data, raster data, and high precision point data. For further information see http://mcmcweb.er.usgs.gov/sdts/.

1.3.4.1.2 SDTS Transportation Network Profile (TNP)

A draft profile was developed in 1995 for transferring non-planar vector data, characteristic of transportation networks. However, the profile was not submitted for formal adoption due to a number of unresolved issues. This standard is expected to address most of these issues and thereby enable resumption of the TNP development. For further information see: http://www.bts.gov/gis/reference/tnp_11.html.

1.3.4.1.3 Facility Identification Data Standard (proposed by the FGDC Facilities Working Group)

The proposed “FGDC Data Content Standard for Location and Identification of Facilities” is intended to develop a Facility Identification data standard that supports identification of place-based objects generally known as facilities. The draft standard incorporates identification of transportation objects which are defined as “Framework Transportation Segments.” The proposed identifiers are defined and derived inconsistently in the two drafts; the Chair of the Ground Transportation Subcommittee has noted this in written comments. The Ground Transportation Subcommittee and the Facilities Working Group will work together to define a consistent identifier or to appropriately delineate the scope of each standard. For further information see http://www.fgdc.gov/standards/status/sub3_3.html .

1.3.4.1.4 Ground Transportation Data Content Standard (proposed by the FGDC Facilities Working Group)

The proposed "Data Content Standard" is intended to provide a common set of entity/attribute/domain definitions for transportation features. The Framework Transportation Identification Standard will provide the foundation on which transportation features in this content standard will be defined, and these two efforts will be closely coordinated. (See http://www.fgdc.gov/standards/status/textstatus.html)

1.3.4.1.5 Address Content Standard (proposed by the FGDC Cultural and Demographic Subcommittee)

The proposed "Address Content Standard" is intended to provide consistency in the maintenance and exchange of address data and enhance its usability.

This proposed standard will provide semantic definitions for components determined by the participants to be integral to the creation, maintenance, sharing, usability, and exchange of addresses and/or address lists. Within this scope, addresses are broadly defined as locators to places where a person or organization may reside or receive communications, but excluding electronic communications. An address list consists of one or more addresses. The "Address Content Standard" will additionally define an entity-relationship model for address data. The "Transportation Identification Standard" will establish criteria for defining and constructing transportation centerline networks to which address ranges and other linear referencing methods may be appended. The "Transportation Identification Standard" development is being coordinated with the address content standard to ensure they are compatible. (See http://www.fgdc.gov/standards/status/sub2_4.html .)

1.3.4.1.6 National Hydrography Dataset

The National Hydrography Dataset project aims to produce a well documented, maintainable and nationally consistent hydrography dataset. This database is also a non-planar topological network, and many of the same concepts will be used in the Transportation Identification Standard. However, the Transportation Identification Standard includes certain enhancements to handle the non-dendritic properties of transportation networks and to allow multiple data developers to contribute and enhance transportation data for the same geographic area. For further information see http://nhd.usgs.gov .

1.3.4.2 Other Organizations

1.3.4.2.1 Vector Product Format

VPF is a standardized format, based on a geo-relational data model, developed by the Defense Mapping Agency (now known as the National Imagery and Mapping Agency (NIMA)), for large geographic databases. VPF is designed to be compatible with a wide variety of applications and products, and allows application software to read data directly from various storage media without prior conversion to an intermediate form. VPF was primarily created as a storage and transfer format for cartographic data developed, maintained, and used by the military. It does not address the specific requirements of non-planar topological networks, nor does it address issues of data enhancement from multiple contributors. Databases constructed using the Transportation Identification Standard should be easily convertible to VPF. For further information see http://164.214.2.59/vpfproto/index.htm .

1.3.4.2.2 Other Models and Standards: GIS-T, Intelligent Transportation Systems, and GDF

The **GIS for Transportation** (GIS-T) research community has been investigating transportation data models for several years, and several candidate conceptual models have been proposed. The **Intelligent Transportation Systems** (ITS) movement has also addressed interoperability across data bases. For the most part, however, these candidate models are unfamiliar to many of the spatial database developers who are currently engaged in NSDI Framework activities.

This proposed standard is intended to use terminology and concepts which are entirely consistent with the GIS-T work, the ITS work, and other transportation conceptual models described elsewhere. At the same time the proposed standard is focused on objectives which are more limited than those advanced by either of these two efforts. These limitations are intended to make the proposed NSDI standard easier to understand

and to implement across multiple database environments. Further information relating to GIS-T can be obtained at http://www4.nas.edu/trb/crp.nsf/All+Projects/NCHRP+20-27(2) . Further information relating to ITS can be obtained at http://itsdeployment.ed.ornl.gov/spatial/files/ITSDEF.htm .

Geographic Data Files format (GDF) is a European standard that is used to describe and transfer road networks and road related data. GDF provides rules of how to capture the data, and how the features, attributes and relations are defined. GDF has been developed in a European project called EDRM (European Digital Road Map). Its primary use will be for car navigation systems, but it is very usable for many other transport and traffic applications like Fleet Management, Dispatch Management, Traffic Analysis, Traffic Management, Automatic Vehicle Locations etc.

GDF version 3.0 has been released and issued to CEN (Central European Normalization) for the voting procedure. After the voting GDF will become the only CEN accepted standard for digital road networks; ISO standardization of GDF is expected in 2000. For further information see http://www.ertico.com/links/gdf/gdf.htm .

1.3.5 Standards Development Procedures

The FGDC initiated work on this proposed standard in December 1997 through a data developers' workshop held to discuss the topic. Workshop participants presented examples of their work on Framework projects, and articulated many common elements. For further information see http://www.fgdc.gov/framework/page04.html .

The first draft of this standard was prepared during the summer and early fall of 1998, for the review of a technical committee called together at the invitation of the Chair of the FGDC Ground Transportation Subcommittee. This is a third draft version, which incorporates comments collected during much of 1999, and is currently in Step 5 (Review Working Draft) of the FGDC Standards Reference Model.

1.3.6 Maintenance Authority

The current maintenance authority for the standard is the United States Department of Transportation (USDOT.) Questions concerning the standard should be addressed to: Mark Bradford, c/o USDOT/BTS K-40, Room #3430, 400 7th St. SW, Washington DC 20590. Copies of this publication are available from the FGDC Secretariat, in care of the U.S. Geological Survey, 590 National Center, Reston, Virginia 20192; telephone (703) 648-5514; facsimile (703) 648-5755; Internet (electronic mail) fgdc@www.fgdc.gov . The text also is available at the FGDC web site http://www.fgdc.gov/standards/ .